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(54) Title: PROCESS FOR THE MANUFACTURE OF PENTAFLUOROETHANE

(57) Abstract

An improved process for the manufacture of CF_3CHF_2 by contacting 1,2-dichloro-1,1,2-trifluoroethane ($\text{CClF}_2\text{CHClF}$) or 1-chloro-1,1,2,2-tetrafluoroethane ($\text{CHF}_2\text{CClF}_2$) or mixtures of CF_3CHCl_2 and $\text{CClF}_2\text{CHClF}$ or mixtures of CF_3CHClF and $\text{CHF}_2\text{CClF}_2$ with HF in the presence of a Cr_2O_3 catalyst prepared by pyrolysis of ammonium dichromate, the reaction being conducted under controlled conditions whereby the production of CF_3CHF_2 is maximized, and the formation of chloropentafluoroethane (CF_3CClF_2) and other perhalo derivatives is minimized. The subject hydrogen-containing compound is useful as a blowing agent, propellant, refrigerant, fire extinguishing agent, or sterilant carrier gas.

BY REACTING CHLOROFLUOROETHANES WITH HYDROGEN FLUORIDE

PREPN. OF PENTAFLUOROETHANE, + USED AS
BLOWING AGENT, PROPELLANT, REFRIGERANT,
FIRE EXTINGUISHING AGENT OR STERILANT
CARRIER GAS, USING CHROMIUM OXIDE CATALYST
AND CONDITIONS TO MINIMIZE PERHALO DERIV. PROD.

(PW) REDUCED OZONE DEPLETION

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TITLE

PROCESS FOR THE MANUFACTURE OF PENTAFLUOROETHANE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent Application Serial No. 07/695,900 (Attorney's Docket No. CH-1983), filed on May 6, 1991, in the names of Vinci M. Felix et al., and entitled "Process for the Manufacture of Pentafluoroethane", the disclosure of which is expressly incorporated by reference.

FIELD OF THE INVENTION

An improved process for the manufacture of pentafluoroethane (CF_3CHF_2) comprising a gas-phase reaction of 2,2-dichloro-1,1,1-trifluoroethane (CF_3CHCl_2) or 1,2-dichloro-1,1,2-trifluoroethane ($\text{CClF}_2\text{CHClF}$) or 1,1,1,2-tetrafluorochloroethane (CF_3CHClF) or 1,1,2,2-tetrafluorochloroethane ($\text{CHF}_2\text{CClF}_2$) or mixtures of CF_3CHCl_2 and $\text{CClF}_2\text{CHClF}$ or mixtures of CF_3CHClF and $\text{CHF}_2\text{CClF}_2$ with HF in the presence of a Cr_2O_3 catalyst prepared by pyrolysis of ammonium dichromate, the reaction being conducted under controlled conditions whereby the production of CF_3CHF_2 is maximized, and the formation of chloropentafluoroethane (CF_3CClF_2) and other perhalo derivatives is minimized. The subject hydrogen-containing compound is useful as a blowing agent, propellant, refrigerant, fire extinguishing agent, sterilant carrier gas, or heavy gas for an aerodynamic wind tunnel. It is desirable for its zero ozone depletion potential.

BACKGROUND OF THE INVENTION

U.S. Patent No. 3,755,477 describes a process for producing fluorinated aliphatic hydrocarbons which comprises fluorinating a halogenated aliphatic hydrocarbon, including tetrachloroethylene and chlorotrifluoroethylene, by reaction in the gas phase with HF in the presence of a steam-treated and calcined chromium oxide catalyst prepared by a multi-step process. Example 23, column 5, shows tetrachloroethylene as a raw material with formation of CF_3CHCl_2 (20%), CF_3CHClF (20%), CF_3CHF_2 (30%), and CF_3CClF_2 (20%) at 10/1 HF/ C_2Cl_4 mole ratio, 5.4 seconds contact time and 350° C reaction temperature. Example 25 shows that, with CF_3CHCl_2 as starting material at 390° C, CF_3CHClF (21%) and

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CF_3CHF_2 (67%) are produced, but again these desirable hydrogen-containing products are accompanied by perhalogenated CF_3CClF_2 (2.5%). The formation of CF_3CClF_2 , 20% in 24 and 2.5% in 25, is objectionable; not only does it constitute a yield loss of the hydrogen-containing substances, but CF_3CClF_2 is extremely close boiling to CF_3CHF_2 with the resulting mix being costly to separate.

U.S. Patent No. 3,258,500 describes a process for the catalytic vapor-phase reaction of HF with halohydrocarbons employing a catalyst that consists essentially of a heat-activated anhydrous chromium (III) oxide which may be supported on alumina. Example 17, column 14, shows that fluorination of tetrachloroethylene with this catalyst at 400° C produces 35.0% pentafluoroethane, 9.2% 1,2-tetrafluorochloroethane, and 3.5% 2,2-dichloro-1,1,1-trifluoroethane. At 300° C the product distribution is 38.3% 1,2-tetrafluorochloroethane, 25.4% pentafluoroethane, and 16.0% 2,2-dichloro-1,1,1-trifluoroethane. Example 20, column 19, shows that chlorotrifluoroethylene at 400° C yields 27% CF_3CHF_2 . It can be seen that, although the yield of the hydrogen-containing products is high, that of pentafluoroethane does not exceed about 35% even at temperatures as high as 400° C.

U.S. Patent No. 4,843,181 discloses a gas phase process for the manufacture of CF_3CHCl_2 and/or CF_3CHClF by contacting a suitable tetrahaloethylene and/or pentahaloethane with HF in the presence of Cr_2O_3 prepared by pyrolysis of $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$, the reaction being conducted under controlled conditions whereby the production of CF_3CHF_2 is minimized.

Canadian Patent No. 849,024 also discloses the formation of CF_3CHF_2 by reaction of HF with a perhaloethylene, e.g., C_2Cl_4 , $\text{CCl}_2=\text{CF}_2$ and $\text{CClF}=\text{CF}_2$, over a hydrous Cr_2O_3 as catalyst, but the CF_3CHF_2 yields are relatively poor.

Canadian Patent No. 1,196,345 discloses that addition of HF to perfluoroethylene over a chromium oxyfluoride as catalyst, which has been activated by treatment with a mixture of HF and F_2 , produces CF_3CHF_2 in high yields. Much inferior yields are obtained using a comparable catalyst activated with HF alone. The disclosed process suffers in that the catalyst activation step not only involves the use of expensive and hazardous molecular fluorine, but requires a back-up scrubbing solution of hexafluoropropylene trimer to scavenge unreacted F_2 . All this represents a loss of F_2 and catalyst activation potential, and further adds to the cost of the process.

The prior art, in general, has shown that CF_3CHCl_2 is obtainable in

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good yields from tetrachloroethylene, a readily available and relatively inexpensive commodity. However, CF_3CHCl_2 as starting material for the production of highly fluorinated hydrogen-containing products by reaction with HF also yields perhalo by-products, evidently via chlorination side reactions, especially when an attempt is made to increase conversion to the desired hydrogen-containing products by operating at high temperatures.

SUMMARY OF THE INVENTION

A process for the preparation of pentafluoroethane which comprises contacting HF with at least one member of the group of CF_3CHCl_2 , $\text{CClF}_2\text{CHClF}$, CF_3CHClF , $\text{CHF}_2\text{CClF}_2$, mixtures of CF_3CHCl_2 and $\text{CClF}_2\text{CHClF}$, mixtures of CF_3CHClF and $\text{CHF}_2\text{CClF}_2$, among others, in the gas phase in the presence of a Cr_2O_3 catalyst at a reactant mole ratio, a feed rate of reactant per weight catalyst, temperature and pressure and for a time effective to form a gas product stream containing CF_3CHF_2 as the predominant component, the catalyst being prepared by pyrolysis of $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$.

Preferably, the Cr_2O_3 catalyst has an alkali metal content of not more than 100 ppm.

Preferably, too, the starting material is CF_3CHCl_2 , and said conditions are controlled such that the CF_3CHF_2 product is substantially free of CF_3CClF_2 .

This invention is based on the discovery that Cr_2O_3 prepared by pyrolysis of $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ is effective to catalyze conversion of CF_3CHCl_2 and the next higher fluorinated intermediate, CF_3CHClF , to CF_3CHF_2 in high yields at high conversions of the starting materials without undue formation of CF_3CClF_2 and other perhalogenated by-products.

Accordingly, it is an object of this invention to provide a process for the production of CF_3CHF_2 using CF_3CHCl_2 as starting material, which results in the formation of CF_3CHF_2 in high yields at high conversions.

Another object of this invention is to provide such process which substantially avoids the formation of close boiling CF_3CClF_2 .

Still another object of this invention is to provide such process as above that utilizes a catalyst that is readily available and is effective in catalyzing the halogen exchange reaction of HF with a reactant comprising at least one member from the group consisting of CF_3CHCl_2 or $\text{CClF}_2\text{CHClF}$ or CF_3CHClF

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CHF₂CClF₂ or mixtures of CF₃CHCl₂ and CClF₂CHClF or mixtures of CF₃CHClF and CHF₂CClF₂, among others, such that the formation of CF₃CHF₂ is maximized.

DETAILS OF THE INVENTION

The Cr₂O₃ catalyst of this invention is prepared by pyrolysis of ammonium dichromate by any method known to the art, including methods such as that described in U.S. Patent No. 4,471,985 which is incorporated herein by reference.

By pyrolysis is meant heating ammonium dichromate to a sufficient temperature and for a sufficient time to cause the following reaction to occur to substantial completion:



For example, ammonium dichromate may be heated in a continuous kiln at 500-700° C, preferably 540-640° C, for 5-20 minutes so that it will undergo an internal oxidation-reduction reaction to produce mainly water, nitrogen and Cr₂O₃. After the water and nitrogen are driven off, the remaining fine powder of Cr₂O₃ may be cooled and compacted so as to increase its bulk density for ease of handling. For example, a bulk density of approximately 400-1440 Kg/m³ may be desirable, and typically 448-512 kg/m³.

The Cr₂O₃ obtained may contain low levels of contaminants which are present as a result of the manufacturing process for the original (NH₄)₂Cr₂O₇. Although not totally destructive of catalyst efficacy, potassium, for example, as a contaminant has an adverse effect on the activity and life of the catalyst of this invention. It is desirable for the amount of potassium and other alkali metals to be 100 ppm by weight or less. The level may be reduced by a water-washing step. While the conditions are not critical, the water-washing step can include forming a slurry containing 5-15% Cr₂O₃, preferably 10%, and deionized water. Stirring of this water slurry can be carried out at 35-65° C for at least one hour, preferably two or more hours. The solids are then recovered by filtration, suitably on a plate and frame filter press. The filter cake can be analyzed for alkali metal content. If its level is 100 ppm by weight or less (dry basis), the solids are, thereafter, dried. If not, the washing step can be repeated to obtain a desired level of alkali metal content.

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The form of the catalyst is not critical and may be used as pellets, powders or granules.

For example, if the catalyst is desired to be in the pellet form, 5-15%, preferably 10%, of chromium acetate and 1-5%, preferably 2% of graphite can be added to the dried solids as pelletization aids. The chromium acetate can be added in aqueous solution of 30-70%, preferably 50% concentration. The resultant paste can be milled to mix the ingredients and then pelletized to the desired size, preferably 0.32 cm x 0.32 cm cylinders. The pellets can be dried at 80-120°C, preferably 105°C, for 8-48 hours, preferably 16-24 hours. The Cr_2O_3 pellets then have a bulk density of 1120-1440 Kg/m^3 for the preferred pellet size and a surface area of 40-57 m^2/g , preferably 45-55 m^2/g . Pore volume is 0.15-0.33 cc/g. The alkali metal content is 100 ppm or less.

Generally, the resulting Cr_2O_3 will be pretreated with HF. It is thought that this converts some of the surface chrome oxide to chrome oxyfluoride. This pretreatment can be accomplished by placing the Cr_2O_3 in a suitable container, which can be the reactor to be used to perform the reaction of the instant invention, and thereafter, passing HF over the pyrolyzed and dried Cr_2O_3 so as to partially saturate the Cr_2O_3 with HF. This is conveniently carried out by passing HF over the Cr_2O_3 for a period of time, for example, about 15 to 300 minutes at a temperature of, for example, about 200°C to about 450°C. The purpose of this pretreatment is to prevent damage to the catalyst due to possible high temperature excursions and resultant coking of the catalyst if the organic reactants were contacted with the catalyst without first having conditioned some of the surface chrome oxide with HF. Nevertheless, this pretreatment is not essential; initial process conditions and equipment could be selected so as to avoid the problem of high temperature and coking of the catalyst.

The contacting of the reactants with HF in the presence of the catalyst, preferably pretreated, of the instant invention is performed at effective temperature, mole ratio and contact time. By effective temperature, mole ratio and contact time is meant the temperatures, mole ratios and contact times which produce a product stream which contains CF_3CHF_2 in a major proportion, preferably in an amount of at least about 50%, more preferably at least about 60%, as determined by gas chromatography.

When employing a reactant comprising at least one member of the group consisting of CF_3CHCl_2 , $\text{CClF}_2\text{CHClF}$, CF_3CHClF , $\text{CHF}_2\text{CClF}_2$, mixtures

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of CF_3CHCl_2 and $\text{CClF}_2\text{CHClF}$, mixtures of CF_3CHClF and $\text{CHF}_2\text{CClF}_2$, among others, the temperature will normally range from about 300° to about 370°C , preferably about 330° to 350°C . The $\text{HF}/\text{CF}_3\text{CHCl}_2$ mole ratio will normally range from 2/1 to about 10/1, preferably from about 3/1 to 8/1. The contact time
5 can vary widely but preferably will be such as to provide an average residence time of from about 10 to 100 seconds, more preferably 20 to 50 seconds.

The pressure is not critical but should be sufficient to maintain HF, the organic reactant and the reaction product stream components in the vapor state at the operating temperature.

10 In general, the higher the temperature, the greater the HF/reactant mole ratio, and the longer the contact time, the greater is the conversion of the reactants to fluorinated products, and the greater is the degree of fluorination of the raw material. The above variables can be balanced, one against the other, so that formation of CF_3CHF_2 is maximized and that of perhalogenated by-products is
15 minimized, preferably to less than about 3%, with that of CF_3CClF_2 to less than 2%, more preferably to less than 1%, said percents being mole percents as determined by gas chromatography.

Unreacted starting material and intermediate compound(s) can be recycled to the reactor for the production of additional CF_3CHF_2 . In some cases,
20 the product stream from the reactor may include one or more intermediates compounds such as $\text{CClF}_2\text{CHClF}$, CF_3CHCl_2 , CF_3CHFCI , $\text{CHF}_2\text{CClF}_2$, among others, which can be recycled to the reactor in order to increase the yield of CF_3CHF_2 . Without wishing to be bound by any particular theory or explanation, it is believed that employing one or more of the CF_3CHF_2 intermediate compounds
25 as a reactant may increase the rate at which CF_3CHF_2 is produced. For example, at least a portion of the starting materials or reactants, which are introduced into the reactor, can comprise at least one intermediate compound(s), that are either virgin and/or obtained as recycled components.

The reaction of the reactants with HF may be conducted in any
30 suitable reactor, included fixed and fluidized bed reactors. The reaction vessel should be constructed from materials which are resistant to the corrosive effects of hydrogen fluoride and hydrogen chloride, such as "Hastelloy" and "Inconel".

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EXAMPLES

The catalyst used in the following runs was Cr_2O_3 prepared by pyrolyzing $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ as described above and had an alkali metal content of 60 ppm. It was in cylindrical pellet form, 1/8 inch long (3.2 mm) and 1/8 inch (3.2 mm) in diameter; its bulk density was about 100 lbs/cubic foot (1602 Kg/m^3). The catalyst was packed in a Schedule 40 "Inconel" 600 U-shaped pipe reactor, 1 inch (25.4 mm) in diameter and 4 feet long (1.2 m), which was immersed in a temperature-controlled molten salt bath which provided isothermal reaction conditions.

The catalyst was activated by gradually heating the packed reactor to 400°C while N_2 gas at a flow rate of 50 ml/minute was passed through it to remove trace water. The temperature was lowered to 200°C , and HF and N_2 gases (1:4 molar ratio) were passed through the reactor. The HF employed for activation and all of the CF_3CHF_2 production runs was commercial grade containing only trace amounts of water. The N_2 flow was decreased with time until neat HF was passing through the reactor. At this point, the temperature was gradually raised to 420°C and maintained for 16 hours.

For hydrofluorination, the reactor temperature was decreased to that indicated in the runs described below. The organic and HF feeds were vaporized external to the salt bath, mixed and fed to a separate catalyst-free section of the pipe reactor, which served as a preheater, before entering the catalyst-packed reactor. The reactant flows were adjusted to give the indicated rates, mole ratios and average residence times, calculated by dividing the volume of the reactor by the volumetric flow rate of the combined HF and organic feeds at the temperature and pressure of operation. The reaction temperature was determined by the salt bath temperature; the pressure was set by a back-pressure regulator.

The reactor effluent was scrubbed with aqueous KOH, and its composition determined with an in-line gas chromatograph. The chromatograph was equipped with a flame ionization detector and used a 20 foot (6.1 m) long, 1/8 inch (3.2 mm) diameter column, packed with "Krytox" perfluorinated polyether on an inert support, and a helium carrier at a flow rate of 20 cc/minute. The gas chromatograph was temperature programmed such that it was held at 40°C for 4 minutes, followed by a temperature ramp of $5^\circ/\text{minute}$ until 180°C was reached and maintained for 5 minutes. The results recorded below are in mole percent.

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EXAMPLE 1

A mixture of HF and CF_3CHCl_2 was fed to the reactor at a mole ratio of $\text{HF}/\text{CF}_3\text{CH}_2\text{Cl}_2 = 6:1$ and a CF_3CHCl_2 feed rate of 0.333 lb/hour (0.151 Kg/hour) per pound of catalyst. The reaction pressure was 100 psig (7.8 atmospheres); the temperature was varied in a series of runs as tabulated in Table 1.

TABLE 1

		Composition, Mole %				
Run	Temp. °C	CF_3CHF_2	CF_3CHClF	CF_3CHCl_2	CF_3CClF_2	Other*
10	1 305	6.6	52.1	40.9	0.0	0.4
	2 315	14.9	57.0	27.6	0.0	0.5
	3 325	36.4	44.0	18.8	0.04	0.8
	4 340	67.5	19.3	11.2	0.22	1.8

* Included $\text{CF}_3\text{CH}_2\text{F}$, $\text{CClF}_2\text{CHF}_2$, $\text{CF}_3\text{CH}_2\text{Cl}$, $\text{CF}_3\text{Cl}_2\text{F}$, $\text{CClF}_2\text{CClF}_2$ and $\text{CClF}_2\text{CHClF}$, each in an amount of less than 1 %.

The results show that the invention catalyst is highly effective to catalyze the conversion of CF_3CHCl_2 to hydrogen-containing products at relatively moderate temperatures, and that the CF_3CHF_2 make increases sharply with increasing CF_3CHCl_2 conversions at increasing temperatures without undue production of perhalo by-products.

Lowering the CF_3CHCl_2 feed rate results in its increased conversion to CF_3CHClF and subsequently to CF_3CHF_2 . This is illustrated in the following Examples.

EXAMPLE 2

The procedure of Example 1 was repeated except that the temperature was held constant at about 326° C. The $\text{HF}/\text{CF}_3\text{CHCl}_2$ mole ratio (MR), the CF_3CHCl_2 feed rate (FR) and the average residence time (ART) in seconds are tabulated in Table 2.

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TABLE 2

Run	MR	FR	CF_3CHF_2	CF_3CHClF	CF_3CHCl_2	Other*	ART
1	6/1	0.333	40.7	42.1	16.4	0.8	30
2	5.4/1	0.3	44.6	42.4	12.5	0.5	29
5 3	5.6/1	0.222	56.2	30.6	12.1	1.1	48
4	10/1	0.111	63.6	26.2	7.0	3.2	60
19	7/1	0.111	70.8	19.8	6.9	2.5	73

* Included were $\text{CF}_3\text{CH}_2\text{F}$, $\text{CClF}_2\text{CHF}_2$, $\text{CF}_3\text{CH}_2\text{Cl}$, $\text{CClF}_2\text{CHClF}$, $\text{CCl}_2\text{FCHClF}$, CF_3CCl_3 and CF_3CClF_2 , each in an amount less than 1%.

It will be noted that conversion of CF_3CHCl_2 to CF_3CHF_2 is high, even at a temperature as low as 326°C , and the conversion increases with decreasing CF_3CHCl_2 feed rate per unit weight of catalyst.

EXAMPLE 3

Example 2 was repeated except the temperature was $350\text{--}351^\circ\text{C}$, and the mole ratios were varied, as noted in Table 3.

TABLE 3

Run	MR	FR	CF_3CHF_2	CF_3CHClF	CF_3CHCl_2	Other*	ART
1	5.2/1	0.333	79.1	11.5	6.9	2.5	32
2	5.1/1	0.333	75.6	13.8	8.2	2.4	29
25 3	6/1	0.222	81.9	10.3	5.2	2.6	43.5
4	5.8/1	0.222	80.2	11.0	6.0	2.8	42.5
5	8/1	0.111	85.9	7.9	3.2	3.0	66

* Included were $\text{CF}_3\text{CH}_2\text{F}$, $\text{CClF}_2\text{CHF}_2$, $\text{CF}_3\text{CH}_2\text{Cl}$, $\text{CClF}_2\text{CHClF}$, CF_3CCl_3 , $\text{CClF}_2\text{CClF}_2$, $\text{CF}_3\text{CCl}_2\text{F}$, $\text{CClF}_2\text{CCl}_2\text{F}$ and CF_3CClF_2 , with the CF_3CClF_2 make reaching a maximum of about 1% in Run 5. No other by-product amounted to more than 1%.

Again, the results demonstrate the outstanding activity of the subject catalyst to promote the production of CF_3CHF_2 at the expense of chlorine-

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-containing perhalo side-products, even at 350° C. The overall results show that, the higher the temperature and the greater the residence time, the higher the conversion and the yields, with the yields of hydrogen-containing products amounting to 90% or better in Runs 3, 4 and 5. This is particularly significant since an effective quantity of at least one of the intermediate compounds such as CF_3CHClF , $\text{CHF}_2\text{CClF}_2$, among others, e.g., listed as "Other" in the above Tables 1-3, can be recycled for further production of the desired pentafluorinated ethane, e.g., the yield of pentafluoroethane is increased. In other words, the intermediate compounds can be reacted individually, or admixed with other intermediate compounds and/or reactants for producing pentafluoroethane.

CLAIMS:

1. A process for the preparation of CF_3CHF_2 comprising:
 - (a) contacting HF with at least one reactant comprising a material selected from the group consisting of CF_3CHCl_2 , $\text{CClF}_2\text{CHClF}$, CF_3CHClF , and $\text{CHF}_2\text{CClF}_2$, in the gas phase in the presence of a solid Cr_2O_3 catalyst at a mole ratio, feed rate of reactant per weight of catalyst, temperature and pressure and for a time effective to form a gas stream comprising CF_3CHF_2 as the predominant component, said catalyst having been prepared by pyrolysis of $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$; and thereafter,
 - (b) separating and recovering CF_3CHF_2 from the product stream.
2. The process of Claim 1 wherein the reaction temperature is in the range of from about 300° to 370°C .
3. The process of Claim 2 wherein the temperature is 330° to 350°C .
4. The process of Claim 3 wherein the CF_3CHF_2 content is at least about 60 mole % of the gas product stream as determined gas-chromatographically.
5. The process of Claim 4 wherein the CF_3CClF_2 content of the gas product stream is less than about 2 mole %.
6. The process of Claim 1 wherein said material comprises a mixture of CF_3CHCl_2 and $\text{CClF}_2\text{CHClF}$.
7. The process of Claim 1 wherein said material comprises a mixture of CF_3CHClF and $\text{CHF}_2\text{CClF}_2$.
8. A process for producing pentafluoroethane comprising the steps of:
 - (a) contacting hydrogen fluoride with a material comprising at least one member selected from the group consisting of $\text{CClF}_2\text{CHClF}$ and $\text{CHF}_2\text{CClF}_2$, in the presence of chrome oxide, wherein at least a portion of said at least one member is converted to a pentafluoroethane without substantial formation of

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perhalogenated by-products, and;
(b) recovering the pentafluoroethane.

9. The process of Claim 8 wherein the reaction temperature ranges
5 from about 300 to 370 C.

10. The process of Claim 8 wherein said chrome oxide has an alkali
metal content of less than about 100 ppm.

10 11. The process of Claim 8 further comprising pretreating said chrome
oxide with hydrogen fluoride before said contacting.

12. The process of Claim 8 further comprising recycling at least a
portion of said at least one member.

15 13. A process for preparing CF_3CHF_2 comprising the steps of:
(a) contacting hydrogen fluoride with a material comprising at least one member of
the group consisting of $\text{CClF}_2\text{CHClF}$ and $\text{CHF}_2\text{CClF}_2$, in the presence of chrome
oxide, to prepare a product comprising CF_3CHF_2 , wherein said product is
20 substantially free of CF_3CClF_2 , and;
(b) recovering said product.

14. A process for increasing the yield of pentafluoroethane
comprising the steps of:
25 (a) contacting hydrogen fluoride with a reactant comprising at least
one member of the group consisting of CF_3CHCl_2 , and CF_3CHClF , in the presence
of chrome oxide,
(b) introducing a quantity of an intermediate compound comprising at
least one member of the group consisting of $\text{CClF}_2\text{CHClF}$, and $\text{CHF}_2\text{CClF}_2$,
30 wherein at least a portion of said reactant and said intermediate compound is
converted to a pentafluoroethane, and the quantity of said intermediate is sufficient
to increase the yield of pentafluoroethane, and;
(c) recovering the pentafluoroethane.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 92/03313

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 C07C17/20; B01J23/26		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	C07C ; B01J	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category [*]	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	WO,A,8 911 467 (DU PONT DE NEMOURS) 30 November 1989 see claims 1,4,9; table 4 ---	1-14
A	EP,A,0 349 298 (DU PONT DE NEMOURS) 3 January 1990 see the whole document ---	1-14
Y	US,A,4 843 181 (GUMPRECHT ET. AL.) 27 June 1989 cited in the application see the whole document ---	1-14
A	EP,A,0 036 123 (HOECHST) 23 September 1981 cited in the application see the whole document & CA,A,1 196 345 5 November 1985 ---	1-14
-/-		
<p>[*] Special categories of cited documents: ¹⁰</p> <p>^{"A"} document defining the general state of the art which is not considered to be of particular relevance</p> <p>^{"E"} earlier document but published on or after the international filing date</p> <p>^{"L"} document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>^{"O"} document referring to an oral disclosure, use, exhibition or other means</p> <p>^{"P"} document published prior to the international filing date but later than the priority date claimed</p> <p>^{"T"} later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>^{"X"} document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>^{"Y"} document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>^{"A"} document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
01 SEPTEMBER 1992	21. 09. 92	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	KISSLER B.E.	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	EP,A,0 403 108 (DU PONT DE NEMOURS) 19 December 1990 see page 3, line 7 - line 11 ---	1-14
Y	EP,A,0 313 061 (DU PONT DE NEMOURS) 26 April 1989 see page 3, line 11 - page 4, line 36 ---	1-14
n,Y	EP,A,0 456 552 (ATOCHM) 13 November 1991 see page 5; example 2 ---	1-14
A	DE,A,2 806 865 (ICI) 5 October 1978 see the whole document ---	1-14
Y	US,A,3 755 477 (FIRTH ET. AL.) 28 August 1973 see table 4 ---	1-14
Y	US,A,3 258 500 (SWAMER ET. AL.) 28 June 1966 cited in the application see column 15; example 20 ---	1-14

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. US 9203313
SA 61762**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for those particulars which are merely given for the purpose of information. 01/09/92

Patent document cited in search report	Publication date	Patent family number(s)	Publication date
WO-A-8911467	30-11-89	AU-A- 3736789	12-12-89
		EP-A- 0416016	13-03-91
		JP-T- 3505328	21-11-91
		US-A- 5008475	16-04-91
EP-A-0349298	03-01-90	AU-B- 612857	18-07-91
		AU-A- 3717989	04-01-90
		JP-A- 2048538	19-02-90
US-A-4843181	27-06-89	AU-A- 2411588	27-04-89
		EP-A- 0313061	26-04-89
		JP-A- 1146832	08-06-89
EP-A-0036123	23-09-81	DE-A- 3009760	24-09-81
		CA-A- 1196345	05-11-85
		JP-A- 5614222	06-11-81
CA-A-1196345	05-11-85	DE-A- 3009760	24-09-81
		EP-A,B 0036123	23-09-81
		JP-A- 5614222	06-11-81
EP-A-0403108	19-12-90	US-A- 5036025	30-07-91
		AU-B- 621268	05-03-92
		AU-A- 5704790	20-12-90
		CA-A- 2017868	13-12-90
		CN-A- 1047983	26-12-90
		JP-A- 3114537	15-05-91
EP-A-0313061	26-04-89	US-A- 4843181	27-06-89
		AU-A- 2411588	27-04-89
		JP-A- 1146832	08-06-89
EP-A-0456552	13-11-91	FR-A- 2661906	15-11-91
		AU-A- 7605391	14-11-91
DE-A-2806865	05-10-78	GB-A- 1589924	20-05-81
		AU-B- 518050	10-09-81
		AU-A- 3311878	16-08-79
		BE-A- 863913	14-08-78
		CA-A- 1119202	02-03-82

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ON INTERNATIONAL PATENT APPLICATION NO. US 9203313
SA 61762**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 01/09/92

Page 2

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-2806865		CA-A- 1124265	25-05-82
		CA-A- 1124264	25-05-82
		FR-A- 2381006	15-09-78
		JP-A- 53105404	13-09-78
		NL-A- 7801741	21-08-78
		US-A- 4158675	19-06-79
US-A-3755477	28-08-73	CA-A- 942927	05-03-74
		DE-A, B, C 2032098	07-01-71
		FR-A- 2051409	02-04-71
		GB-A- 1307224	14-02-73
		NL-A- 7009179	29-12-70
US-A-3258500		None	

EPO FORM PACT

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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